



Composite Beam Shear Connection Design and Detailing Practices for Australian Steel Decks

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Executive Summary

Efficient utilization of welded-stud shear connectors through economic detailing of novel types of reinforcement in the concrete slab of a composite beam has been the outcome of world-leading Australian research conducted for well over a decade at UWS/CCTR and the former BHP Melbourne Research Laboratories (MRL). New generic forms of ladder and waveform reinforcement have been developed for use with profiled steel sheeting to enhance the strength and ductility of shear connectors, and improve on-site construction practices and quality.

The research initially focussed on Australian steel sheeting profiles with narrow re-entrant steel ribs. The most recent work explores the influence of profiles with wide open steel ribs commonly used in developed countries, in particular so-called trapezoidal profiles. With the advent of trapezoidal profiles suitable for use in composite beams in Australia, and in the absence of specific rules in Australian Standard AS 2327.1 covering decks with wide open steel ribs, design engineers in consulting and construction companies have to make important decisions about designing and detailing the shear connection between the concrete slab and the steel beam of simply-supported and continuous composite beams if they want to take advantage of these longer-spanning products.

Differences of opinion about suitable design and detailing practices for composite beams have arisen following major research investigations undertaken over many years around the world including in Australia. However, the research has produced conclusive evidence that in their present form many of the major composite design Standards, Specifications and Codes from overseas countries (American, British, European, German, etc.) should be used with caution when designing and detailing the shear connection, since they can potentially lead to reduced safety for all types of secondary and primary beams, in either internal or edge beam configurations, depending on the type of profiled steel sheeting being used.

This document has been written to briefly explain the background to this statement, and to provide the very latest advice about the topic to practitioners in Australia. The research undertaken at UWS/CCTR and MRL has focussed on developing practical solutions to a number of the major failure modes that have been identified, which in contrast to what has been occurring in Australia, are causing increasingly more prescriptive and restrictive design rules being developed overseas.

By taking advantage of a range of innovative steel reinforcing products (and also a stud performance-enhancing device) supplied in Australia by OneSteel Reinforcing Pty Limited, the numerous benefits and economic advantages of using modern, long-spanning trapezoidal steel decks, as well as all other types of decks suitable for composite steel-frame building construction, are made available to Australian industry without compromising the strength of composite buildings and the safety of its occupants.

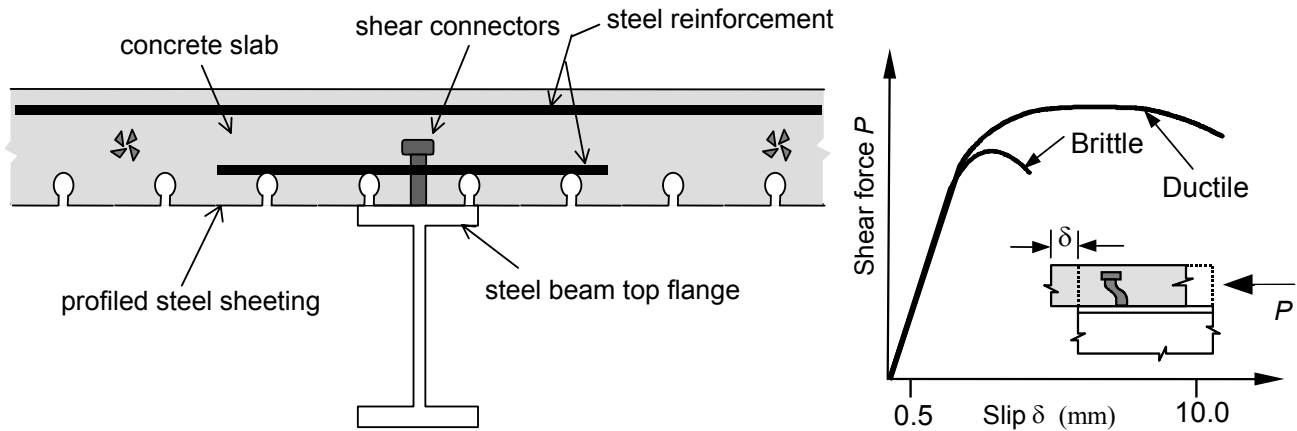
A product checklist is given at the end of this document to assist Australian design engineers in this process.

Acknowledgement

This review of current developments for the shear connection of composite beams has generously been supported by OneSteel Reinforcing Pty Limited.

1. Shear Connection in Composite Beams

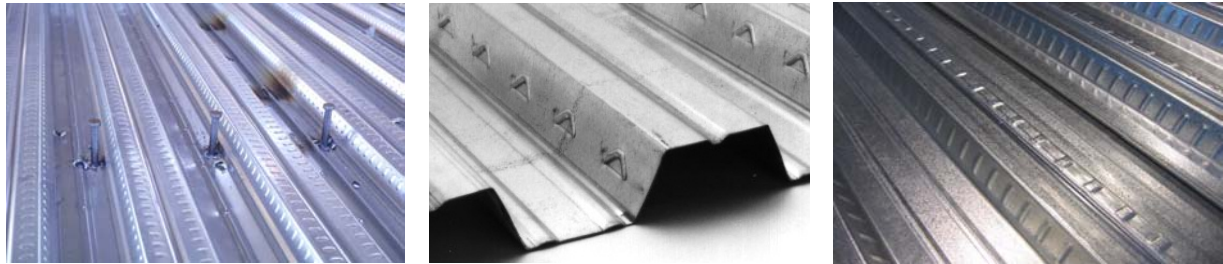
- (a) The shear connection of a conventional composite beam comprises five components that can all influence behaviour. They include the shear connectors, profiled steel sheeting, slab reinforcement (including longitudinal bars if beams are continuous), concrete slab and steel beam top flange. Behaviour is defined as *ductile* or *brittle* depending on the shear-slip curve.



- (b) Other, new and innovative components have been developed in Australia to improve the performance and constructability of the shear connection that include *special ladder and waveform types of longitudinal shear reinforcement*, and a *shear stud performance-enhancing device* that reduces the tendency for studs to punch through the sides of the steel ribs of the profiled steel sheeting (*rib punch-through failure*) improving strength and ductility.
- (c) Design of the shear connection is important because it affects:
- choice of a suitable ultimate strength design method for the composite beam [13,36];
 - vertical deflection of the composite beam;
 - economics and speed of construction;
 - stability of the steel beam;
 - safety of composite beam against collapsing; while
 - large forces are involved (up to about 13 tonnes per 19 mm diameter welded stud, i.e. in a solid slab, a welded stud can reach an ultimate shear capacity of $A_s f_u$, where A_s = cross-sectional area of stud and f_u = steel tensile strength (typically 450 MPa)).
- (d) The ultimate strength of most composite beams is governed by connector shear capacity as partial shear connection is the most economical solution to resist factored loads.
- (e) Apart from ongoing international concerns, for example [2,11,16,17,18,19,20,22,27,28a,29,30,32,33,43,44], other factors also dictate that a conservative approach should be taken when designing the shear connection of composite beams in Australia:
- presence of any type of profiled steel sheeting that creates wide voids in the concrete;
 - absolute minimum slabs thickness demanded by economics (acoustics/fire excepted);
 - modelling errors in laboratory push-out and beam tests;
 - unknown tension forces developed in studs (particularly primary beams), and where there is significant Vierendeel action in regions of large web penetrations;
 - potential causes of welding failures of shear studs fired through steel decking (gap beneath pan, longitudinal stiffeners, sheet galvanizing, paint, equipment, water, dirt);
 - limited site supervision and inspection of stud welding by trained personnel;
 - possible construction errors (stud placement inaccuracies, e.g. incomplete removal of stud ceramic weld ferrules, favourable vs unfavourable sides – see §2(c));
 - repeated loading effects (carparks, truck loading ramps, plant rooms);
 - simply-supported composite beams, which provide limited opportunity for moment redistribution or alternative load-transfer paths in the case of member failure; and
 - limited ductility of steel beam end connections to accommodate end rotations [28b].

2. Evolution of Australian and Overseas Profiled Steel Sheeting Types

- (a) Only four years ago, all the major Australian steel decking profiles for use with welded studs had a re-entrant narrow open steel rib, a closed lap-joint, or a combination of both giving rise to “closed-rib profiles” and narrow “open-rib profiles” as currently defined in AS 2327.1 [36]. These profiles were favoured for various reasons including the fact that it has been possible to treat a composite slab as a solid slab when designing the shear connection, provided the studs are kept certain minimum distances away from the narrow open ribs (different for secondary and primary beams). Maximum unpropped spans have reached about 3.0 metres.
- (b) About that time, a UK-designed trapezoidal profiled steel sheeting was introduced into Australia (KF70 is produced by Fielders as part of their KingFlor® range of decks [14]). It has allowed unpropped spans to increase to over 3.5 metres. Concrete savings have resulted on account of the wide open trapezoidal rib.
- (c) Trapezoidal decks have been used for decades in America where they were first developed, with depths typically up to 76 mm in unpropped spans up to about 4.0 metres. They normally have a longitudinal stiffener in the middle of the pan which makes it impossible to place the studs centrally, thus giving rise to “unfavourable” and “favourable” sides in secondary beams. This has become a controversial construction issue, so some manufacturers have replaced the central longitudinal stiffener with a pair of stiffeners (e.g. KF70), and possibly an off-centred lap joint, allowing studs to be placed centrally in pans and improve reliability.



- (d) In recent times, some steel decking manufacturers in Australia and overseas have developed trapezoidal decks with more widely-spaced, deeper steel ribs (for increased spans) and narrower concrete ribs (for less concrete). Testing has shown that design formulae in many Standards may incorrectly indicate that welded studs should achieve full solid-slab strength.
- (e) In the UK in particular [39], in the absence of specific testing some decking manufacturers have designed new decks according to the well-known formula for reduction factor, *k*, in BS 5950:3.1 [6] which was originally derived in America from results of full-scale beam tests:

$$Q_{k.com} = k Q_{k.solid}$$

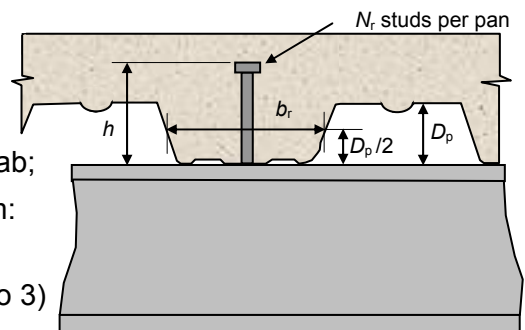
where –

$Q_{k.solid}$ = characteristic shear capacity in solid slab;

$Q_{k.com}$ = characteristic shear capacity in composite slab;

and for the decking ribs perpendicular to the steel beam:

$$k = \left(\frac{0.85}{\sqrt{N_r}} \right) \left(\frac{b_r}{D_p} \right) \left[\left(\frac{h}{D_p} - 1 \right) \right] \leq 1.0; 0.8; 0.6 \text{ (for } N_r=1 \text{ to } 3)$$

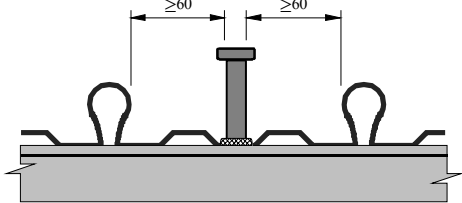


Note: In Eurocode 4: Part 1.1 [13] (see §3(d)) the coefficient 0.85 is replaced by 0.7. A similar formula is given in the Code for when the decking ribs are parallel to the steel beam, with the term $0.85/\sqrt{N_r}$ replaced by 0.6.

To increase their spanning capability, the new decks in the UK (such as that described in §2(b)) have an upwardly orientated, top longitudinal stiffener (see photograph on right directly above). Testing has shown that using the formula for *k* ignoring the top stiffener when defining D_p [38], which gives significantly greater values for *k* than if the real overall depth is used, may be unsafe [29]. Concerns around the world have been raised about the unconservative predictions that this formula for *k* gives.

- (f) New decks can be designed for solid-slab status of shear studs, e.g. TRUSSDEK® [23b].

3. Australian and Major Overseas Composite Beam Design Standards

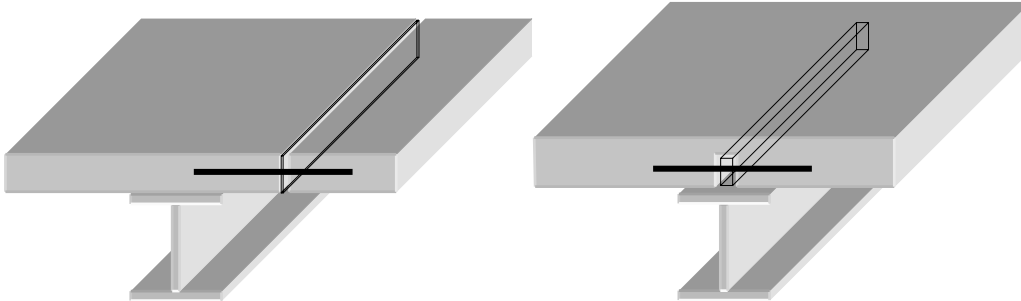
- (a) Australian Standard AS 2327.1 [36] for the design of simply-supported composite beams has recently been revised (new 2003 edition). Based on many years of experimental research, e.g. [25,26,28a] it has major advantages and fundamental differences to overseas Standards:
- detailing rules ensure shear connection behaviour is ductile to allow plastic design of the shear connection, and brittle behaviour is not permitted;
 - the use of wide open-rib profiles is not covered because it has been uncertain how to account for the adverse effect of the steel decking when determining the design shear capacity of shear connectors and reinforcing the slab (formulae for reduction factor k in BS 5950:3.1 [6] were in the 1980 version of AS 2327.1 but were removed by the committee);
 - detailing rules avoid having to reduce the design shear capacity of studs compared to a solid slab, leading to highly efficient shear connection;
 - shear connectors may be placed very close to “closed” ribs without any penalty, but need to be kept at least 60 mm from open ribs;
 - a restriction that minimum degree of shear connection $\beta \geq 0.5$ at the cross-section of maximum design bending moment is independent of span and does not apply to any other potentially critical cross-sections being assessed for adequate strength;
 - decking may not be used as longitudinal shear reinforcement in secondary beams;
 - secondary composite edge beams are detailed differently with vertical reinforcement through a potential horizontal failure surface which can give rise to rib-shearing failure;
 - a load-sharing factor allows the design shear capacity of groups of connectors to be rated higher than single connectors, leading to fewer connectors in many cases; and
 - no specific performance criteria or standardised testing methods for the shear connection are currently presented in the Standard, but are under development.
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- (b) British Standard BS 5950: Part 3.1 [6] for the design of simply-supported and continuous composite beams was published in 1990. Some features of the Standard are:
- edge beams include heavy U-bars that do not prevent rib-shearing failure [27];
 - detailing rules do not ensure ductile shear connection [5,17,27,28a,29,30,32,43];
 - formula for factor k in §2(e) is copied from an early edition of the AISC Specification [1];
 - a similar formula for a reduction factor in primary beams is also used (see §2(e) note);
 - new-generation UK decks are not specifically addressed in the Standard [29]; and
 - although haunches formed in primary beams with solid concrete slabs require transverse reinforcement within the depth of the haunch, there is no such requirement when the haunch is formed using profiled steel sheeting, even if the sheeting is split longitudinally over the steel beam to form a wider haunch [5].

Owing to significant safety concerns [29,30], the shear connection design provisions in the British Standard are currently being reviewed through industry-funded research [17].

- (c) Draft DIN 18800: Part 5 [10] produced in 1999 and an earlier 1981 DIN-Richtlinien [9] are used in Germany to design simply-supported and continuous composite beams. DIN 18800 is very similar to Eurocode 4, while [9] is interesting because it refers to the use of a shear stud performance-enhancing device (50 mm diameter spring) that can be placed over a welded stud in a solid slab to increase the shear stiffness of the shear connection.
- (d) Draft Eurocode 4: Part 1.1 [13] (June 2003) contains the latest European rules for designing composite beams. Value of k is reduced up to a further 30 percent depending on thickness of steel sheeting and number of studs in pan [16]. Code does not allow designers to assume shear connectors are all placed on favourable side, and defines ductile shear connection.
- (e) AISC Load and Resistance Factor Design Specification for Structural Steel Buildings [1] (December 1999) contains the original formula for k . As a result of new American research [33], significant concern about the unconservativeness of this formula has been raised and an entirely new approach is contained in the draft 2005 AISC Specification for comment [3].

4. Conventional Longitudinal Shear Reinforcement in Composite Beams

- (a) Failure of the concrete slab of a composite beam by shearing longitudinally through the concrete can significantly reduce the strength and ductility of the shear connection, and must be prevented by the use of appropriate reinforcement.
- (b) It has been assumed that longitudinal shear failure can occur over several simplified longitudinal shear surfaces that can ultimately lead to a part or most of the concrete slab separating from the composite beam, e.g. Type 1 and 2 shear surfaces in AS 2327.1 [36]:



- (c) Horizontal, longitudinal shear reinforcement placed transverse to the longitudinal axis of the steel beam is designed by calculation in accordance with AS 2327.1 for solid and composite slabs [28a]. A similar approach is adopted in BS 5950 and Eurocode 4 for solid slabs.
- (d) Extra reinforcement must be concentrated in the concrete slab in the vicinity of the shear connectors. Horizontal reinforcing steel in the form of mesh or loose bars, primarily being used as flexural or shrinkage and temperature steel, can be taken into account. Common practice is for design engineers to specify short additional bars which can be relatively labour intensive to place, or strips of ordinary mesh which can be costly due to the time involved to cut them on site and the extra 20-40% mass of steel. The slab is normally thin, making it difficult to fit the reinforcement in the cover slab over the tops of the sheeting ribs and reliably meet concrete cover requirements for durability. In edge beams heavy U-bars must be specified, according to BS 5950 and Eurocode 4, which were developed to control longitudinal splitting in solid slabs. AS 2327.1 requires some vertical reinforcement in edge beams with narrow outstands or high shear stud intensities [25,26,27,28a,30,31].



- (e) European practice is to completely omit any reinforcement below the head of the studs in both secondary and primary composite beams incorporating profiled steel sheeting whenever possible [8,21,39,43]. Reliance may be placed on the steel decking itself acting as longitudinal shear reinforcement [20], provided it is appropriately anchored, or it is assumed that any reduction in stud shear strength due to the absence of any low-down conventional reinforcement has been allowed for by using the reduction factor k .
- (f) In Eurocode 4, a primary beam haunch formed without profiled steel sheeting must be reinforced in its base region (bars must be 40 mm under head of stud). According to Eurocode 4 this is unnecessary if the haunch is formed with profiled steel sheeting, unless the sheeting is split and inadequately anchored along its edges, but even so it is still acceptable to lengthen the stud and lay the lowest transverse bars on top of the deck [20].
- (g) American [15] and UK [34] research has demonstrated that steel fibres in normal intensities do not overcome the major problems experienced using conventional reinforcement (mesh or bar) in secondary beams detailed in accordance with existing design Standards [1,6,13,etc.].

5. Potential Local Failure Modes and Weakening of Shear Connection

- (a) Concrete crushing in base region of stud (only affects stud shear strength if concrete weak).



- (b) Studs shear through shank base just above weld (best possible behaviour if slip < 10 mm at peak shear force) – tearing of sheeting may also occur, increasing the shear resistance.



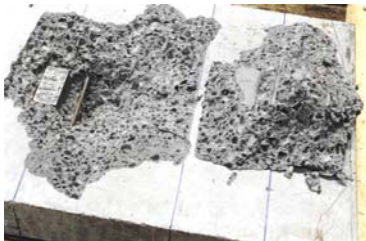
- (c) Concrete punch-through around shear connectors *.



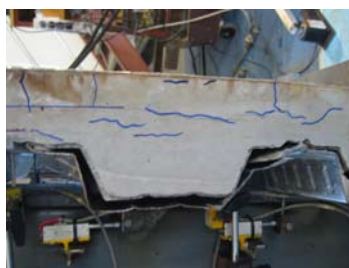
- (d) Haunch-shear (resulting in delamination of cover slab) at a primary beam haunch **.



- (e) Concrete blow-out in top of slab where there is a high concentration of shear connectors.



- (f) Separation of sheeting prevents it from acting as effective longitudinal shear reinforcement.



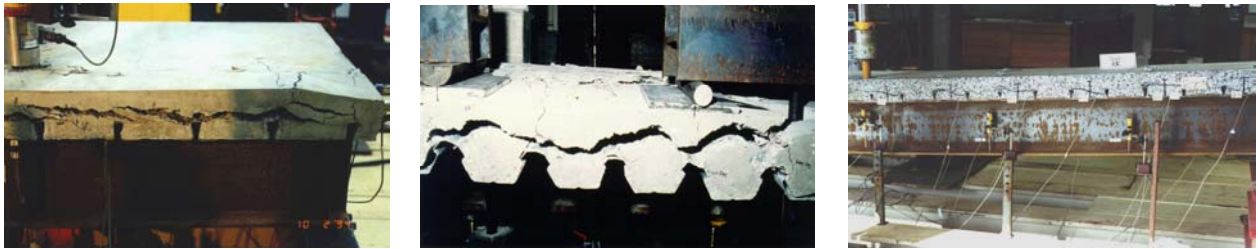
(g) Rib punch-through in a secondary beam ***.



(h) Concrete pull-out in a secondary beam (particularly likely with stud pairs) ****.



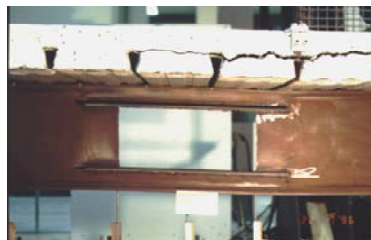
(i) Rib-shearing in a secondary beam ****.



(j) Longitudinal splitting emanating from base region, fanning of concrete struts and lateral rib punch-through in primary beam haunches unreinforced below the concrete cover slab *****.



(k) Delamination in region of large web penetrations undergoing significant Vierendeel action ****.



Legend of products needed to either prevent failure mode altogether or limit effect {see §8}:

* =horizontal reinforcement, ladder or waveform {§8(a),(c)}

** =handle-bar reinforcement (attached to ladder) {§8(d)} – solid-slab status may be achieved

*** =shear stud performance-enhancing device {§8(e)} – solid-slab status may be achieved

**** =waveform reinforcement {§8(b)}

***** =ladder reinforcement (possibly with handle-bars) {§8(d)} – solid-slab status may be achieved

6. Consequences of Premature Failure or Brittle Behaviour of Shear Connection

- (a) Brittle shear connection is less economical since greater variability causes reduced design shear capacity, and strength of beam may be sensitive to changes in loading configuration.
- (b) The argument that no collapses or significant signs of distress have been reported, so change is unnecessary, demonstrates a lack of understanding because:
 - problem cases may not become public knowledge due to legal privilege;
 - real extent to which safety of structures is reduced is unknown, and very likely to be more than acceptable in critical cases, e.g. “.the proposed changes to the Specification are warranted because it has been well documented that the level of reliability, or if you prefer factor of safety, is not what is implied by the Specification.” [2];
 - simply an argument against change, which deters research and development work that can ultimately lead to better, more economical and safer solutions and systems;
 - problems not solved, simply since want to maintain short-term commercial gains; and
 - potential liability continues to grow, ultimately threatening viability of whole system since the engineering profession may eventually lose confidence in the system.
- (c) Beams are less susceptible when the total number of shear connectors is not governed by the bending strength of a critical cross-section (a typical, uniformly-loaded secondary beam):
 - degree of shear connection at mid-span governed by shear connector maximum spacing requirement or by vertical deflection criterion, i.e. flexural stiffness.
- (d) Beams are more susceptible when the number of shear connectors in a critical shear span is governed by the bending strength of a critical cross-section, for example:
 - secondary beam with large steel beam and thin slab;
 - typical primary beam with concentrated loads (secondary beams) along its length;
 - beams with large web penetrations near beam ends; or
 - edge beam with heavy concentrated loads, e.g. façade support points.
- (e) Cost of proof testing to investigate owner’s concerns and/or remedial work (and possibly having to mount legal defence) is potentially vastly greater than the cost of having used special reinforcement or shear stud performance-enhancing device – cheap insurance policy.
- (f) Beams with sub-standard shear connection subjected to repeated loading are more vulnerable to progressive damage over the course of their life, e.g. heavily-trafficked ramps.
- (g) Beams can be damaged if overloaded, and increased beam deflections and cracking of concrete along lines of shear connectors create long-term strength, serviceability, aesthetic and durability problems, particularly in structures open to the weather, e.g. car parks.



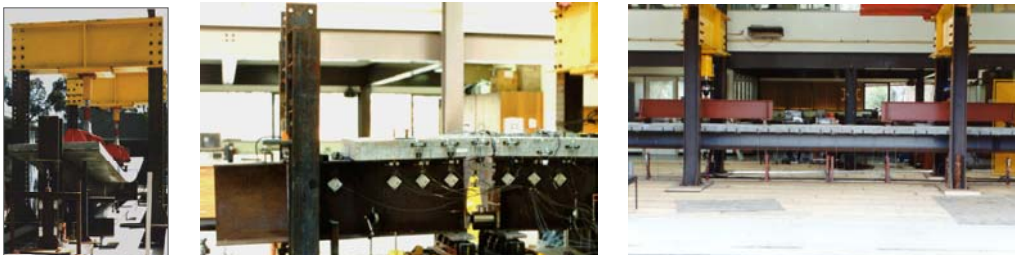
- (h) The rotational demand on beam steel end connections at ultimate load is increased if the beam flexural stiffness is reduced due to weak shear connectors, and the end connections can fail well before the beam they support attains its maximum moment capacity.
- (i) Conservative loading (e.g. compactus areas) could result in apparent sudden collapse. For example, little deflection of a stiff primary beam just before maximum strength is reached.
- (j) Redundancy of beams in floor system cannot necessarily be relied upon, e.g. may be an isolated member which design Standards, Codes and Specifications allow.

7. Laboratory Testing

- (a) Design Standards, Codes and Specifications are becoming increasingly more prescriptive as new decks are introduced and new problems are found by testing [3,13,16,19,29,32,33,44].
- (b) Stud design strengths are progressively reducing and restrictions are becoming more onerous [3,7,13], e.g. may only be allowed one stud per pan for ductile performance [13].
- (c) Performance-based design allows innovative, economical solutions to be developed through testing, promotes product development, creates a level playing ground for competing products, and improves safety by reducing the risk of sub-standard performance occurring.
- (d) Brittle and ductile behaviour can be ascertained from testing, and design engineers can rate each system and design accordingly. Eurocode 4 [13] has a ductility criterion for push-out tests, which will be difficult to meet unless current details and practices are improved [17,34].
- (e) Owing to the complex behaviour of the shear connection and the many variables involved, laboratory testing is essential, particularly as new decks are continually being developed.
- (f) Many types of push-out test set-ups and specimens have been developed; modern one-sided versions used in Australia and overseas offer labour, time and cost savings [28a,44].



- (g) Beam testing is much more costly to perform, e.g. additional measurements to estimate stud shear forces (accuracy is an issue [29,42]), and modelling assumptions still arise [26,29,42].



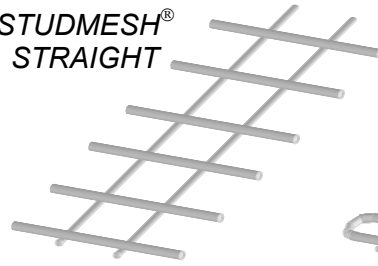
- (h) American testing [11,33], upon which changes [2,3] to the LRFD Specification are based, has included two-sided push-out specimens with a “yoke device placed around the perimeter of the specimen” that “prevents the metal deck from peeling away from the beam flange”, potentially suppressing concrete pull-out, rib-shearing, haunch-shear and concrete blow-out.
- (i) UK testing [17,43] has sometimes benefited from the use of continuous, angled and lipped steel edge trim around the perimeter of push-out specimens, potentially clamping the slab together and suppressing concrete pull-out, rib-shearing and haunch-shear failure modes. Trim would prevent unrealistic “back breaking”, but additional top reinforcement can do this.
- (j) Standardised test methods are required, but are likely to take considerable time to develop and reach national/international acceptance. Preferably, for economic reasons, laboratory tests should be designed to allow the results to be used as generally as possible.
- (k) New types of reinforcement [5,23,31] and a stud performance-enhancing device [12] have been trialled in push-out and beam tests, with further development work continuing. All these products (DECKMESH[®], STUDMESH[®], HAUNCHMESH[™] and STUDRING[®]) are available for use by any decking manufacturer in Australia provided appropriate testing determined by UWS and OneSteel Reinforcing is undertaken. (Note: DECKMESH[®], STUDMESH[®], HAUNCHMESH[™] and STUDRING[®] are all patent pending.) Design engineers do not have to perform calculations to use the reinforcing products DECKMESH[®], STUDMESH[®] and HAUNCHMESH[™] since appropriate design tables are provided that depend on type of deck, type of composite beam, shear connector intensity, concrete strength, etc., e.g. [24,28a].

8. Novel Australian Mesh Solutions and Shear Stud Performance-Enhancing Device from OneSteel Reinforcing Pty Limited

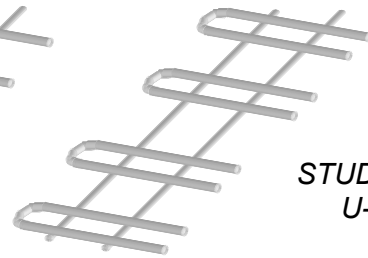
(a) Ladder reinforcement in secondary internal and edge beams – **STUDMESH® LADDER** [23a].



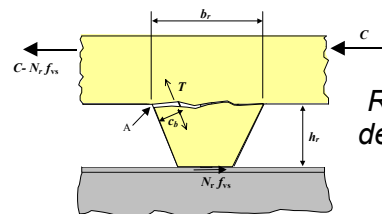
**STUDMESH®
STRAIGHT**



**STUDMESH®
U-BAR**



(b) Waveform reinforcement in secondary edge beams to prevent rib-shearing failure (see design model) or in internal beams to prevent concrete pull-out failure – **DECKMESH®** [23a].



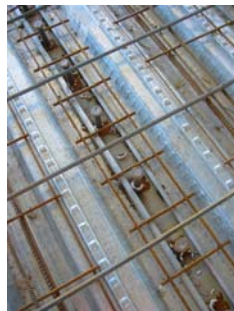
(c) Planar waveform reinforcement in secondary beams – **STUDMESH® WAVEFORM**.



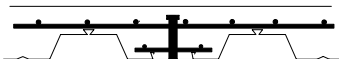
DECKMESH, STUDMESH, HAUNCHMESH and STUDRING are trademarks authorised for use by OneSteel Reinforcing Pty Limited: www.reinforcing.com

(d) Ladder and handle-bar reinforcement in primary beam haunches – **HAUNCHMESH™** [23a].

**HAUNCHMESH™
STRAIGHT**
prevents
longitudinal
splitting & lateral
rib punch-through



**HAUNCHMESH™
HANDLE-BAR**
prevents haunch-shear (as
well as longitudinal splitting
& lateral rib punch-through)
when stud intensity is high
and/ or ribs are narrow

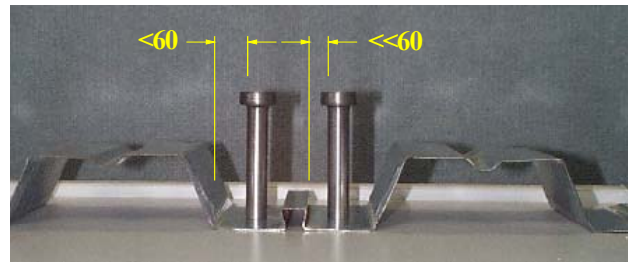


(e) Shear stud performance-enhancing device to reduce effect of rib punch-through failure in secondary beams - **STUDRING®** [12,30] (testing of early prototype shown in photographs).



9. Advice to Australian Design Engineers

- (a) When choosing a deck and the most suitable layout of steel beams, do not only consider the spanning capability of the deck and the magnitude of any concrete savings, but also take into account the effect the deck has on the strength and efficiency of the shear connection.
- (b) Use the latest edition of AS 2327.1–2003 [36] to design the shear connection of beams incorporating solid slabs or equivalent composite slabs with closed-rib profiles or narrow open-rib profiles. With appropriate modification, the design rules in this Standard and other documents, e.g. [4], can also be used as a basis to design beams incorporating trapezoidal decks provided the shear connection behaves in a ductile manner, e.g. for KF70 [24,40,41].
- (c) Be careful if using any overseas Standards, Codes or Specifications [1,3,6,7,10,13,37] to design the shear connection when using a deck not covered directly by AS 2327.1.
- (d) Seek all available information from decking manufactures before embarking on design.
- (e) Manufacturers may have versions of DECKMESH[®] & HAUNCHMESH[™] available for their decks. These products are manufactured and supplied by OneSteel Reinforcing, and are validated for each new deck by analysis and testing at the University of Western Sydney.
- (f) Understand the potential failure modes of the shear connection for the different types of beams being designed, e.g. secondary vs primary; edge vs internal (see [28a] and §5).
- (g) Favour ductile over brittle failure modes. For many reasons brittle failure should be avoided.
- (h) Make sure recommendations for designing/detailing the shear connection are well founded.
- (i) Be aware of accessory items for primary beams to form wide concrete haunches efficiently.
- (j) Ensure that the latest forms of ladder and waveform reinforcement are available for the particular deck and beam detail (see §10) – laboratory testing must have been performed.
- (k) Use of non-composite secondary edge beams may be considered if the waveform reinforcement DECKMESH is not available for a particular deck.
- (l) Determine whether STUDRING is available to enhance stud performance (shear capacity and ductility –see §10) for the deck being considered – again laboratory testing is necessary.
- (m) Understand all aspects of stud detailing and any limitations or restrictions for the deck being used, and show details clearly on project drawings and include in project specification.
- (n) Do not assume that the shear connectors will be located in the best possible positions in the decking pans unless foolproof means are available for ensuring this occurs in practice.
- (o) Shear studs may be welded directly to the steel beams in the fabrication shop rather than through the decking if it is used in single spans and there is adequate side cover to studs.
- (p) Learn stud welding qualification requirements [35] and perform thorough site supervision.



- (q) Be aware of the potential problems, e.g. brittleness, that arise using decks (see just above, right) where it is not possible to place studs a reasonable distance away from any steel ribs.
- (r) Be very careful when designing composite beams for which the assumed strength of the shear connection is vital for their structural integrity and occupant safety, e.g. primary beams.
- (s) Steel fibres cannot act as a substitute for reinforcement as per §8 – the shear connector forces are too concentrated for these to be functional or economical.
- (t) Whenever possible in typical, thin slabs, use only bars, or short bars placed perpendicularly over the steel beams and lapped with mesh adjacent to the steel beams, and follow specific recommendations about using ladder and waveform reinforcements to ensure important concrete cover requirements are met. Use specific labour-saving reinforcement solutions like STUDMESH whenever possible in secondary and primary beams – see §10.

10. Australian Design Engineers' Product Checklist – Composite Beam Shear Connection Design and Detailing Practices for Australian Steel Decks

The following product checklist has been prepared to assist engineers designing and detailing composite beams incorporating Australian steel decks. In particular, it summarises when the generic forms of ladder and waveform steel reinforcing products, and the stud performance-enhancing device, described in §8 and supplied by OneSteel Reinforcing Pty Limited, should be used depending on the geometry of the steel deck. It also provides some important information about 19 mm diameter stud shear connector placement in the presence of profiled steel sheeting.

(a) Geometry of deck conforms to §1.2.4 of AS 2327.1 [36], e.g. Fielders' KingFlor® KF57, RF55; Lysaght's Bondek® II; Stramit's Condeck® HP.

Composite beam details						Product from OneSteel Reinforcing Pty Limited			
Profile type	Beam type	Beam location	Haunch detail	Proximity of studs to rib	Max. no. studs	DECKMESH <i>waveform</i>	HAUNCHMESH <i>ladder (w/wo handlebars)</i>	STUDMESH <i>ladder or waveform</i>	STUDRING
closed-rib	secondary	internal	n/a	unrestricted	2 per sect.	n/a	n/a	✓	n/a
"	"	edge	n/a	unrestricted	2 per sect.	✓✓✓✓	n/a	✓	n/a
"	primary	int. or edge	whole pan	unrestricted	2 per sect.	n/a	n/a	✓	n/a
open-rib	secondary	internal	n/a	≥60 mm	2 per pan	n/a	n/a	✓	<i>under investigation</i>
"	"	edge	n/a	≥60 mm	2 per pan	✓✓✓✓	n/a	✓	<i>under investigation</i>
"	primary	int. or edge	whole pan	≥30 mm	2 per sect.	n/a	<i>under investigation</i>	✓	n/a

(b) Geometry of deck (trapezoidal profile with wide open steel ribs) does not conform to §1.2.4 of AS 2327.1, e.g. Fielders' KF70.

Composite beam details						Product from OneSteel Reinforcing Pty Limited			
Profile type	Beam type	Beam location	Haunch detail	Proximity of studs to rib	Max. no. studs	DECKMESH <i>waveform</i>	HAUNCHMESH <i>ladder (w/wo handlebars)</i>	STUDMESH <i>ladder or waveform</i>	STUDRING
trapezoid	secondary	internal	n/a	central i/p	2 per pan	✓✓✓	n/a	✓	✓ or ✓✓ ¹
"	"	edge	n/a	central i/p	2 per pan	✓✓	n/a	✓	✓ or ✓✓ ¹
"	primary	int. or edge	split deck ²	central	1 per sect.	n/a	✓✓	n/a	n/a

Legend: n/a = not applicable w/wo = with or without ✓ = recommended ✓✓✓ = highly recommended ✓✓✓✓ = needed to meet
i/p = if possible ✓✓ = highly recommended when stud pairs are used code requirement AS 2327.1

Note: When using HAUNCHMESH, to avoid clashing the longitudinal spacing of the shear studs should suit the spacing of the transverse bars of HAUNCHMESH for the range of meshes available, e.g. [24].

¹ The need for STUDRING depends on a variety of factors. If the shear connection is ductile without the ring and shear strength is not critical, then studs should be used alone. However, rib punch-through failure can be brittle, in which case use of STUDRING is highly recommended, as it also is if additional shear strength is required from each stud in decks with narrow pans.

² A version of HAUNCHMESH has been specially developed for decking laid continuously over the steel beams to form narrow haunches with a single line of studs in normal steel ribs [24].

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